Attorney Docket: DQIP-156

SPECIFICATION

TO ALL WHOM IT MAY CONCERN:

BE IT KNOWN that we, Douglas D. Hall, and David P. Herd and Richard Buckenham, have invented new and useful improvements in a

RADIAL PENETRATOR ASSEMBLY AND METHOD

of which the following is a specification:

CERTIFICATE OF MAILING

I hereby certify that this correspondence and all referenced enclosures are being deposited by me with the United States Postal Service, postage prepaid as Express Mail No.: EV317506593US, in an envelope addressed to: Commissioner of Patents, BOX NEW PATENT APPLICATION, Alexandria, Virginia 22313-1450 on this the 25th day of September, 2003.

Tricia Skarpa

Tricia Skarpa

Attorney Docket: DRIA-156

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Name

RADIAL PENETRATOR ASSEMBLY AND METHOD

Field of the Invention

The present invention relates to a radial penetrator assembly and, more particularly, to a radial penetrator assembly with metal-to-metal seals and a sleeve-shaped adapter extending radially from a wellhead housing.

Background of the Invention

Some oilfield applications involve conducting high pressure fluids through a tubing hanger, through a bridge across an annular gap, then through an outer wellhead housing, such as a tubing spool or wellhead body, with all critical seals being metal-to-metal seals. A conduit may be attached to the inner body to seal internal pressure within the conduit, while the opposing outer end of the conduit may be sealed with the outer wellhead housing. However, the two end attachments to which the conduit ends are affixed and pass through typically possess some misalignment, either vertically or laterally (circumferentially). Past practice has typically employed small diameter OD, thin walled conduit tubing that could easily be bent to compensate for any misalignment, while still maintaining sufficient straightness to achieve the conditions necessary to ensure that the pressure fittings could perform their sealing functions at each end of the conduit. The conduit and fittings extending between the hanger and the outer wellhead housing are commonly referred to as a radial penetrator, since the fluid is directed radially through the housing wall. Numerous patents have been directed to radial penetrator assemblies, including U.S. Patents 6,047,776, 6,050,338, 6,119,773, and 6,470,971, and many of the references cited in these patents.

For a larger diameter, thicker walled conduit, the above methods work neither consistently nor well. It is much more difficult to bend large diameter, thick walled tubing, which begins to resemble small diameter pipe. Side loads sufficient to flex the pipe sideways to complete make-up of the fittings may cause the tube to assume an

elliptical shape, which makes it difficult to assure a reliable external seal. These side loads are also difficult to generate manually, as required for field make-up operations.

Past practices include making up the first end fitting exiting from the top of a tubing hanger with a pre-bent conduit which directs the flow to a substantially horizontal plane. Feedthrough of continuous conduits is conventionally through the tubing hanger axially, then the conduit may be bent and manually fed through the wellhead wall. This fairly simplistic and reliable operation conventionally may only be accomplished with small diameter, thin-wall tubing with sufficient flexibility to manually bend the lines. Passage of the bent conduit through the wellhead wall from the outside may also require a very large port through the wellhead wall. Substantial offsets, both vertically and laterally, may occur and may be compensated for externally.

The disadvantage of the prior art are overcome by the present invention, and an improved radial penetrator assembly and method are hereinafter disclosed.

Summary of the Invention

A radial penetrator assembly is provided for sealingly conducting fluid through the passageway in a wall of a wellhead housing having a central bore, with the fluid passing into a port in an inner member positioned within the central bore of the wellhead housing. The radial penetrator assembly includes a flexible tube extending radially between the passageway in the wellhead housing in the port and the inner member, a sleeve-shaped adapter extending radially from a wellhead housing to an adapter bore, sealed to the passageway in the wellhead housing, and a radially outer seal between a radially outer portion of the adapter and the radially outer portion of a flexible tube, such that the flexibility of the tube permits an inner portion axis of the tube to be axially offset or slanted with respect to an outer portion axis of the tube. In a suitable embodiment, the radially outer seal is a metal-to-metal seal between an outer sealing surface on the flexible tube of the inner sealing surface on the adapter.

In one embodiment, the inner member may comprise of a tubular hanger for suspending a tubular string in the well, and the port in the tubular hanger and a throughport which extends to an end surface of the tubular hanger. The radially alignment member may be used for selectively aligning the inner member with the central bore of the wellhead housing. A radial spacing between a radially inner end of a flexible tube and a radially outer end of a flexible tube preferably is in excess of about 30% greater than the radial spacing between a radially inner end of the flexible tube and radially outer end of the passageway in the wall of the outer member.

A method of the invention includes radially extending the flexible tube between the passageway and the wellhead housing and the port in the inner member, and providing a sleeve-shaped adapter extending radially from the wellhead housing and having an adapter bore sealed to the passageway of the wellhead housing. The radially outer seal is formed between a radially outer portion of the adapter and the radially outer portion of a flexible tube, such that the flexibility of the tube permits an inner portion axis of the tube to be axially offset or slanted with respect to an outer portion axis of the tube.

A particular feature of the invention involves the use of seals such that test fluid may be introduced to verify the holding of a selected working pressure. This test operation may be performed at the surface, thereby providing assurance to the operator prior to downhole installation that the system will perform as intended.

A significant advantage of the present invention is that the technique is relatively simple and involves highly reliable and commercially available components.

These and further features and advantages of this invention will become apparent from the following detailed description, wherein reference is made to the figures in the accompanying drawings.

Brief Description of the Drawings

Figures 1-6A illustrate the wellhead assembly during various stages of installation.

Figure 1 illustrates the wellhead housing with a tubing hanger above a landing shoulder, prior to being sealed within the bore of the wellhead housing.

Figures 2 and 3 illustrate the wellhead housing with a tubing hanger in a subsequent stage of installation. Figures 3A illustrates in greater detail the radial penetrator assembly shown in Figure 3.

Figure 4 illustrates the wellhead housing with a tubing hanger in another stage of installation, while Figures 4A and 4B illustrate in greater detail, the radial penetrator assembly shown in Figure 4.

Figure 5 illustrates the radial penetrator in a wellhead housing in another stage of installation.

Figure 6 discloses the wellhead housing with a tubing hanger and a pair of radial penetrators in another stage of installation, with the penetrator shown in greater detail in Figure 6A.

Detailed Description of Preferred Embodiments

A radial penetrator assembly as shown in detail in Figure 5 may be used for sealingly conducting fluid through a passageway in a wall of a wellhead housing 18, as shown in Figure 6, with the wellhead housing 18 conventionally having a central bore 19 and a lower end with a flange 17 for sealing engagement with other oilfield equipment. The radial penetrator assembly 10 as shown in Figure 5 extends from the wellhead housing 18 radially inward to an entrance/egress port 15 in an inner member, such as the tubular hanger 14 shown in Figure 1, with a hanger 14 having a throughport 16, conventionally extending downward to one or more tubing lines 12 extending further downward through the wellhead housing 18 and typically into the well. The interior of tubing 12 as shown in Figure 6 is thus in sealed fluid communication with the radially outward end 22 of the flexible tube 20, as shown in Figure 5. The wellhead housing 18 as shown in Figure 1 may also have an inner cylindrical bore 19. The tubular hanger 14, which acts as the inner member, may have a generally cylindrical outer diameter.

The radial penetrator assembly of the present invention is particularly suitable for providing the desired flow path between a wellhead housing 18 and a tubular hanger for suspending a tubular string in a well. In other embodiments, the tubular hanger may be replaced by a plug or other inner member for landing in the central bore of the wellhead housing 18 and having a port in general alignment with the radial passageway in the wall of the wellhead housing. The port may not continue through the inner member in a downward manner as shown for the tubular hanger, and instead may extend axially upward from the port to a top surface of the plug, or may extend to some other surface of the inner member. Also, the passageway in the wall of the wellhead housing may supply fluid to a port in an inner member which has no outlet, and instead may, for example, supply an opening pressure or a closing pressure to a valve within the inner member 14. Also, it should be understood that the term "wellhead housing" as used herein refers to the outer housing or spool of oilfield equipment which has a central bore for receiving the inner member and one or more passageways in the wall of the outer member each for receiving the radial penetrator assembly as disclosed herein.

A feature of the invention is that the various metal seals required for the penetrator assembly are not formed by threads, and instead threads are preferably used to removably attach and detach the radial penetrator assembly from the wellhead housing and the inner member. Also, the flexible tube which extends radially between the wellhead housing and the throughport in the inner member is preferably of the type which has a substantially fixed axial length, i.e., the flexible tube itself is not constructed in a manner such that its axial length may be easily stretched or reduced in the manner of an elongate bellows. High reliability and low cost are thus achieved with the uniform diameter metal flexible tube as disclosed herein, which may be fabricated from steel, inconel, copper, or other flexible yet high burst pressure material.

The radial penetrator assembly as disclosed herein preferably includes three metal-to-metal seals which allows the assembly to be reliably installed, easily removed, then again installed in the wellhead housing and the tubular hanger. As shown in Figure 5, a first, inner seal is formed by the tapered nose 21 of tube 20 in contact with a contact seat 32 in the tubing hanger body 14. This first, inner seal is energized and retained by the threaded gland 64. A second, radially intermediate seal, which optionally may be supplemented by an elastomeric seal 38, seals between the inner portion of the adapter 30 and the wellhead housing 18. Finally, a third, outer metal-to-metal seal is energized by a threaded gland 66, sealing between the outer end of the adapter 30 and the outer end of the flexible tube 20. This construction allows a cover flange 52 as shown in Figure 6A to be easily installed, so that fluids may be reliably transmitted between the control or injection line 42 as shown in Figure 6A and the flow line 12 as shown in Figure 6.

The tubular hanger 14 as shown in Figure 6 includes a central bore 24 in fluid communication with and extending above the bore 19 in the wellhead housing 18. The upper end 25 of the tubular hanger 14 as shown in Figure 2 may be provided with one or more seals 26 for sealing engagement with the lower end (not shown) of a tubular spool adapter which may be stabbed over the top of the tubing hanger and locked to the wellhead housing 18.

Those skilled in the art will appreciate that the tubing hanger 14 as shown in Figure 1 is shown raised from its landed position on the wellhead housing, and has been landed on shoulder 28 of housing 18 in Figure 2, with seals 29 providing a static seal between an outer diameter of the tubular hanger and an inner cylindrical bore of the wellhead housing. Once landed, the tubular hanger may be locked axially within the wellhead housing by a C-ring 85 which engages grooves provided in the wellhead housing. The upper end of the wellhead housing may also include one or more outer grooves 88 for receiving a locking member to structurally connect with the wellhead housing 18 with a tubing spool adapter (not shown) or other housing.

Figure 2 illustrates a conventional threaded plug 87 secured to the tubular hanger 14 for closing off the throughport 15 in the hanger, and another conventional threaded plug 89 secured to the wall of the wellhead housing to close off the radially extending passageway 88 through the housing wall, as shown in Figure 1. Still referring to Figure 2, the radial penetrator assembly as disclosed herein conveniently accomplishes its desired goal of sealingly conducting fluid even though the central axis 86 of the plug 87, and thus the central axis of the throughport 15 in the tubular hanger, is not in alignment with the central axis 90 of the plug 89, and thus the central axis of the radial passageway 88 in wellhead housing 18.

A suitable sequence for installing the radial penetrator assembly at the surface may thus start with the assumption that the tubing hanger 14 has already landed on the shoulder 28 of the wellhead housing 18 as shown in Figure 2, and that the axis 86 of the radially outer port in the outer surface of the tubular hanger may not be in precise alignment with the axis 90 in the radial passageway in the wellhead housing.

Various forms of a conventional alignment members on one of the housing and tubing hanger may be used in cooperation with a groove on the other of the wellhead housing and the tubing hanger to automatically align the tubing hanger 14 within the wellhead housing, so that the landed tubing hanger is properly positioned when lowered onto the shoulder 28. In most cases, misalignment between the axes 86 and 90 as shown in Figure 2 may be slight once the tubing hanger is properly landed on the

wellhead housing.- Even a slight misalignment may, however, make it difficult to obtain the desired metal-to-metal seals for fluid communication between the one or more tubes 12 and the corresponding radial passageways in the wall of the wellhead housing 18.

Referring again to Figure 5, the radial penetrator assembly 10 includes three primary components. Elongate flexible tube 20 preferably has a substantially uniform diameter outer surface 21 along substantially its entire length. A generally sleeve-shaped adapter 30 is positioned within a passageway 88 of the wellhead housing 18, extending radially from the wellhead housing 18 to an adapter passageway 33 of the adapter 30. The seal 38 seals the passageway 88 between the adapter 30 and the wellhead housing 18. The flexibility of the tube 20 permits an inner portion axis 92 of the tube 22 to be axially offset or slanted with respect to an outer portion axis 94 of the tube 20. More particularly, a re-sealable metal-to-metal seal is preferably obtained between an outer sealing surface of the flexible tube 20, which preferably is the outer substantially uniform diameter cylindrical surface 21, and the inner sealing surface 34 on the adapter 66, which energizes the seal. In a preferred embodiment, the inner threaded plug 64 as shown in Figure 5 may be threaded to the tubular hanger 14 to energize the seal between the tapered nose 21 of the flexible 20 and the contact seat 32 in the tubing hanger body 14. The threaded glands 64, 66 thus allow the adapter assembly to be easily installed between the tubular hanger, but also allow the adapter assembly to be easily removed. Thus, for example, the tubing hanger subsequently may be raised above the wellhead housing after the seal assembly as shown in Figure 2 has been retracted, thereby allowing the tubular suspended in the well from the tubing hanger 14 to be retrieved through the wellhead housing 18.

Still referring to Figure 5, it should be understood that the purpose of the adapter 30 is to lengthen the axial spacing between the threaded plugs 64 and 66 from that which would conventionally be provided if the inner plug 64 were between the inner end 65 between an outer end 22 of the tube 20 in the wellhead housing 18. More particularly, the axial length of the adapter 30 is preferably controlled so that a radial

spacing between a radially inner end 65 of a metal tube 22 and a radially outer end 67 of the metal tube is at least about 30% greater than the radial spacing between the radially inner end 65 of the tube 20 and the radially outer end 95 (Figure 3) of the passageway in the wall of the wellhead housing 18. Adapter 30 thus results in a substantial increase in the length of the flexible tube 70, thereby providing the flexibility between the ends of the tube to achieve the desired sealing functions, as disclosed herein. In most applications, this radial spacing between the inner end of the tube will be about 30% or more, and in many applications at least about 40%, greater than the spacing between the end of the flexible tube and the outer end of the passageway in the wall of the outer housing.

A tapered nose 21 of tube 20 and inner threaded gland 64 as shown in Figure 3A may be installed with the centerline 72 of the threaded gland 64 aligned with the cetnerline 92 of the throughport in the hanger 14. The threaded gland 64 may be tightened to the desired torque using a sleeve-shaped threading tool 76 as shown in Figure 3A that allows a deep enough reach to perform the task. Installation of the threaded gland 64 and the tapered nose 21 of tube 20 may result in vertical and/or lateral (circumferential) offset of the centerline 92 with respect tot he centerline 94, as shown in Figure 5. Conventional wrench flats 77 on tool 76 allow the tool and thus the inner socket end of the tool to make-up or break-out the threaded gland 64 from the hanger 14.

A sleeve-shaped adapter 30 as shown in Figure 4 may then be installed over the protruding end of the tube 20. The adaptor 30 preferably incorporates a long internal taper 36 as shown in Figure 5 that allows easy installation over the tube 20 without generating prohibitive bending loads, and also provides precision final centralization of the tube 20 as it exits the adapter 30. This feature counteracts the lateral offset and some of the angular misalignment. The adapter 30 may then be tightened, creating a metal seal with the outer housing 18. This static metal-to-metal seal between the adapter 30 and the housing 18 may be supplemented with an elastomeric, e.g., rubber O-ring seal 38, as shown in Figure 5.

In order to allow tightening of the adapter, it may first be necessary to apply a side load to the threaded gland 22 using an alignment tool 82 to straighten the threaded gland into sufficient lateral and angular alignment with the adapter 30.

As shown in Figure 4A, an alignment tool 82 may be again employed to correct any final angular misalignment between the threaded gland 66 and the adapter 30 by applying a corrective side load, as needed. As the side load is applied, simultaneously the outer threaded gland 66 may be tightened to a desired final torque level. The radial penetrator assembly thus forms a conduit with one secured by threaded gland 64 to the hanger 14, and the opposing end sealed by adapter 30 to the housing 18.

Once the penetrator assembly has been installed as shown in Figure 5, a cover flange 52 as shown in Figure 6 may be installed pressure-tight over the outer end of the penetrator assembly protruding from the outside of the outer body, with a bore in tubing line 12 in fluid communication with the tube 20. In one embodiment, this flange 52 is used with an internal valve 54 as shown in Figure 6A communicating with the through passageway in the tube 20 to control fluid flow to a respective line 12. The flange 52 may be used with an external conduit or tubing 42 through which fluids may be transferred. Static seal 58 may seal the flange 52 to the housing 18, while conventional bolts 59 allow the flange to be easily installed and removed from the wellhead housing. The entire flow circuit thus desirably employs metal-to-metal seals throughout.

Figure 6A illustrates one embodiment of the assembly in a test configuration. An alternate embodiment may conduct the fluid through the test flange without using an integral valve. Once the cover flange 52 has been placed over the radial penetrator subassembly, the flange ring gasket may be tested to verify pressure integrity. Figure 6A shows the adapter 30 with an O-ring seal 100, which allows the introduction of test fluid between the O-ring and the metal gasket 58 through test port 101 by removing plug 102. This ensures the sealing integrity of seal 58 without introducing test fluid into port 16 via tube 20.

The radial penetrator assembly of the present invention is particularly suited for providing a desired fluid path between a wellhead housing and a tubular hanger for

suspending a tubular string in a well. In other embodiments, the tubular hanger may be replaced by some type of plug or other inner member which is landed in the central bore of the wellhead housing and has a port in general alignment with the radial passageway in the wall of the wellhead housing.

The radial penetrator assembly as disclosed herein preferably includes three metal-to-metal seals which allow the assembly to be reliably installed, easily removed, and then again installed between the wellhead housing and the tubular hanger: (1) a radial inner seal energized by the gland 64 sealing between the radially inner end of the tube 20 and the tubular hanger 14, (2) a radially intermediate seal, which optionally may be supplemented by an elastomeric seal, between the inner portion of the adapter 30 and the wellhead housing 18, and finally (3) a radially outer metal-to-metal seal energized by the threaded gland 66 sealing between the outer end of the adapter 30 and the outer end of the flexible tube 20.

A preferred new design includes an O-ring on the body of the adaptor or gland 30. This allows test fluid to be introduced through the port 101 shown in Figure 6A, thereby allowing a verifiable demonstration that the gasket 58 holds pressure without introducing test fluid into port 16. The user may then be shown that the connection meets all regulations.

While preferred embodiments of the present invention have been illustrated in detail, it is apparent that other modifications and adaptations of the preferred embodiments will occur to those skilled in the art. The embodiments shown and described are thus exemplary, and various other modifications to the preferred embodiments may be made which are within the spirit of the invention. Accordingly, it is to be expressly understood that such modifications and adaptations are within the scope of the present invention, which is defined in the following claims.